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Special Issue: **Multiple policy entries for a sustainable food system in Portugal: overview, challenges and solutions**

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What is the best policy to reduce the 'un'sustainable use of pesticides in Portugal

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Abstract

Pesticides go hand in hand with modern farming. In fact, farmers face many pressures to use pesticides, but the most important reason is to avoid economic losses and maximize gains. The application of synthetic pesticides to food crops in the European Union exceeds 400,000 tonnes per year, with numerous negative health and environmental effects.

The objective of this article is to explore the potential for introducing an optimal pesticide policy in Portugal. The impact of different policy strategies (regulation, subsidizing, certification), their applicability and impacts among different stakeholders are assessed to support a proposal for the most suitable policy.

A pesticide policy grounded on certification processes (the current one), where consumers have the option to choose food products without pesticides, imposes the choice of using or not pesticides on the producer and excludes vulnerable segments of the population that do not have access to pesticide free food mainly for economic reasons. Pesticide policies grounded on economic incentives (subsidies) to compensate the costs of using expensive pesticide alternatives also leaves the choice to the farmer, that most times adopts an easy to use and less risky option based on pesticide use, even when having the option to receive an economic compensation. The pesticide policy grounded on taxes over pesticides, based on their toxicity (regulation), to compensate pesticide externalities, seems to be the best choice. In this case, food obtained with or without pesticides will have the same price and that will shift farmers towards more sustainable cultivation practices.

Keywords: Taxes, subsidizing, certification, pesticide use, sustainable farming.
JEL classification: Q, Q1, Q18.

Resumo

O uso de pesticidas anda de mãos dadas com a agricultura moderna. De facto, os agricultores são pressionados para usar pesticidas, principalmente com o objetivo de evitar perdas económicas e

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maximizar produtividades. O uso de pesticidas na agricultura na União Europeia excede as 360,000 toneladas por ano, com inúmeros efeitos negativos na saúde e no ambiente.

O objetivo deste artigo é explorar a possibilidade de introdução de uma melhor política para o uso de pesticidas em Portugal. O impacto de diferentes opções políticas (regulação, subsídios, certificação), a sua aplicabilidade e o impacto em diferentes atores são avaliados para apoiar a definição da política mais adequada.

Uma política baseada em sistemas de certificação (a política atual), em que os consumidores têm a opção de escolher alimentos isentos de pesticidas, coloca a decisão de usar ou não pesticidas no agricultor e exclui os segmentos da população vulneráveis que não têm acesso a estes alimentos pesticidas por razões económicas. As políticas baseadas em incentivos económicos (subsídios) para os custos decorrentes da opção por alternativas ao uso de pesticidas, também coloca a decisão no agricultor, que normalmente opta por uma solução mais fácil e de menor risco, mesmo perante a possibilidade de receber uma compensação financeira. Uma política de uso de pesticidas baseada na introdução de taxas associadas à sua toxicidade (regulação), para compensar externalidades inerentes do seu uso, parece ser a melhor opção. Neste caso, os alimentos com ou sem pesticidas terão o mesmo preço e isso contribuirá para que os agricultores adotem práticas agrícolas mais sustentáveis.

Palavras-chave: Taxas, subsídios, certificação, uso de pesticidas, agricultura sustentável.
Classificção JEL: Q, Q1, Q18.

1. INTRODUCTION

1.1. The 'un'sustainable use of pesticides

Pesticides, intensively used in Europe and throughout the world against pests and diseases on cultivated plants and weeds in agriculture, and therefore related to an increase in farm productivity, severely affect the environment, biodiversity and non-target organisms including human health (Ewald et al., 2015; Hallmann et al., 2017; Sánchez-Bayo and Wyckhuys, 2019). Pesticides are chemical compounds with a component-specific inherent toxicity (Claeys et al., 2011) that causes the contamination of all environmental compartments (air, water and soil) via leaching, run-off or evaporation, affect habitats and contribute to biodiversity loss, including large reductions of insect populations (Ewald et al., 2015; Hallmann et al., 2017; DEFRA, 2019; Sánchez-Bayo and Wyckhuys, 2019) leading to the deterioration of ecosystem services, such as insect-mediated pollination, soil formation and composition, and the provision of clean drinking water. That could pose potential risks to human health (Zhang et al., 2015), while residues in animal feed pose risks to animal health and can enter the food chain (Bjørling-Poulsen et al., 2008). Population studies show that it is quite common to find detectable concentrations of pesticides in the human urine, such as glyphosate (Niemman et al., 2015; Gillezeau et al., 2019). The numerous negative health effects associated with chemical pesticides include dermatological, gastrointestinal, neurological, carcinogenic, respiratory, reproductive, and endocrine effects. Furthermore, high occupational, accidental, or intentional exposure to pesticides can result in hospitalization and death (Nicolopoulou-Stamati et al., 2016).

Agriculture has been criticised for its negative impacts, but the dimension and the focus on pesticides are unique. Moving towards environment-friendly and healthy production systems is thus a strong demand by European citizens and a strong political commitment. However, quantity, quality, and price of agricultural goods produced by European plant production systems are currently heavily dependent on chemical control of pests, diseases, and weeds. Transition to agriculture free from pesticides is a huge challenge that prompts to a complete reassessment of production practices. At the European level, the directive 2009/128/EC has defined the first reduction goals by calling for the reduction of risks and dependency on pesticides.

Despite the existing European and national regulatory restrictions and the fact that the authorisation process is expensive and pushes pesticide prices up, the actual consumption and use of pesticides in the EU has not decreased over the last years, nor has the percentage of food and feed samples in which residues of pesticides exceed maximum regulatory limits - it remains in the vicinity of 5% (Albouy et al., 2016; EFSA, 2019), or the presence of pesticides in aquatic and soil environment that

are commonly found at concentrations well above the regulatory limit, and there is no sign of decrease or the reduction of biodiversity losses due to intensive agricultural production.

1.2. The need to 'call for action' and adopt policies that aim to reduce the 'un'necessary use of pesticides

Therefore, it is urgent to establish policy measures that aim to diminish the use of pesticides in Europe, and, particularly, in Portugal, reducing the risks and impacts of pesticide use on human health and the environment and promoting the adoption of alternative agricultural approaches or techniques. Policy measures may include regulation (prohibition, limitation and/or taxation of pesticides), subsidizing (support to the adoption of agricultural practices that are alternative to pesticide use), or certification (price differentiation based on consumers demand of certified food products).

The overall goal of the present policy study is to support policy makers towards the definition of the most adequate policy measures that might ensure an effective reduction of pesticide use and its impacts on human health, both at consumers and farmers level, and on the environment, in Portugal.

The design and application of a pesticide policy framework should consider (1) the production level - trends in pesticide use (overuse or underuse), farmers' behaviour in face of the introduction of a pesticide tax or similar, indirect effects of pesticide use, (2) alternatives to pesticide use, (3) attitudes towards risk and uncertainty related to pesticides application, and (4) the value of pesticides to consumers (e.g., the willingness to pay (WTP) for lower pesticide use).

The study will point out potential policy strategies and consider their applicability at national level and its impacts among different stakeholders (farmers, pesticide sellers, consumers, environmentalists, decision makers, etc).

2. PESTICIDES: THE BENEFITS AND THE IMPACTS

Pests, diseases, and weeds are the main competitors with humans for agricultural products, particularly when it comes from crops grown under high productivity conditions, causing important losses (Oerke and Dehne, 2004; Savary et al., 2012; Oliveira et al., 2014; Savary et al., 2019). The damage caused by these crop enemies constitutes a major factor in reducing the productivity of many crops, either in the field (preharvest) or later during storage (post-harvest). An average of 35% of potential crop yield is lost to preharvest pests worldwide and post-harvest losses (transport, preprocessing, storage, processing, packaging, marketing, and plate waste) may achieve another 35% (Oerke, 2006; Molden, 2007; Popp et al., 2012), although these estimates present large fluctuations due to a number of factors related to environmental conditions, the plant species being cultivated, the agricultural practices, farmer socioeconomic conditions, and the level of technology used (Oerke and Dehne, 2004; Oliveira et al., 2014).

Since the advent of pesticides, in the middle of the 20th century, they are the most used method to control harmful or unwanted organisms, such as pests, diseases and weeds, in agriculture, but also to control the growth of plants and pests on non-agricultural surfaces. The use of pesticides brings various benefits (mostly economic), particularly for farmers. Pesticides are used to improve or safeguard agricultural yields and the quality of agricultural products. They also minimise labour input, they can limit soil erosion by reducing tillage, and they are also used outside the agricultural sector, for instance to preserve wood (Cooper and Dobson, 2007).

Pesticide defenders usually sustain that plant protection in general and the use of pesticides have an obvious role in meeting the growing demand for food quality and quantity (Strange and Scott, 2005; Popp et al., 2012; Bonner and Alavanja, 2017).

But, because of their intrinsic properties, pesticides have huge negative impacts: they can be harmful to non-target organisms and can have unwanted adverse effects on human health and the environment. Pesticides are linked to a range of serious illnesses and diseases from respiratory problems to cancer. Since the best-selling book Silent Spring (1962), from Raquel Carson, about biological magnification, and the impact large spectrum chlorinated hydrocarbon pesticides such as DDT, the concern about pesticide effects is rising.

2.1. Reducing the pesticide use will impact negatively (or positively) at the production level?

Information on the production structure of pesticide use includes trends in pesticide use (overuse or underuse), and the direction and extent farmers' behaviour will change following the introduction of a pesticide tax. In particular, will a pesticide price increase lead to significantly decreased pesticide use?

In the past 70 years the use of pesticides in agriculture has increased dramatically and now amounts to more than 2.5 billion kg per year, with Europe being the leading continent in terms of pesticides sales (Lamichhane et al., 2016). In Portugal, pesticide use per hectare duplicated between 1990 and 2014 (from 3.04 to 6.84 kg/ha), being among the European countries with highest consumption (Fig. 1) (Roser, 2020).

Conventional pesticides (i.e., only pesticides synthesized by the agrochemical companies) offer numerous benefits, essentially related with increased crop yields, improved food safety, human health, and quality of life, and reduced labor, energy use, and environmental degradation (Cooper and Dobson, 2007). At global level estimates indicates that the losses prevented by crop protection more than 400 billion euros (Roser, 2020).

But the use of conventional pesticides led to a range of problems that will end up being paid by the society. A few studies from European countries have estimated the external costs of pesticide use: over 260 and 117 million euros for the United Kingdom and Germany, respectively (Pretty et al., 2001; Waibel et al., 1999). Other external costs of pesticides include a severe decline in the number of birds, butterflies, bees, and several other species, pesticide resistance among pest populations and a high percentage of workers poisoned by pesticides in Europe (about 27% of farmers) (Lamichhane et al., 2016).

2.2. What are the farmers' perspectives?

Farmers use pesticides to avoid economic losses and maximize gains, and once the technique is used, it may be impossible to revert to the previous process, except at a high cost, even when the cost of production employing the new technique eventually rises above that of the old. The reality is that farmers are under pressure to maximise yield because high yields are equated with high profits. Avoiding the use of pesticides, increases the risks and the financial losses that overcome the costs required to purchase pesticides and prevent that from happening (Yan, 2017).

The pesticide user, seller and regulator face risks and different sources of uncertainties. Production uncertainty related to different technological options, as well as many other variables, can affect pesticide use decisions. Technical, economic, and social constraints will have implications for time and intensity of regulation per se but also on the choice of the policy instrument.

Farmers' choices, in terms of crop protection strategies, may consider a set of available plant protection methods (Figure 1) and integrate appropriate measures that discourage the development of populations of harmful organisms and keep the use of plant protection products and other forms of intervention to levels that are economically and ecologically justified and reduce or minimize risks to human health and the environment. These strategies are supported in agroecological principles, that emphasize the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural mechanisms for pest management (Gliessman, 2014; Lamichhane et al., 2016; Altieri, 2018).

FIGURE 1: CROP PROTECTION METHODS ALTERNATIVE TO PESTICIDE USE

Source: Lamichhane et al., 2016; Costa et al., 2019.

Research on the effects of existing active ingredients on the environment and health and its costs/value/risk and a comparison with alternatives to pesticide use (such as biological or biotechnical control – Table 1) enable to introduce differentiated policy measures and trigger the development of effective alternatives and encourage its adoption.

TABLE 1: ALTERNATIVE CROP PROTECTION MEASURES IN APPLE ORCHARDS

	Pest/Disease	Alternative control method
Pests	*Cydia pomonella* (L.)	— disrupting mating — mass capture — granulose virus — *Bacillus thuringiensis*
	Dysaphis plantaginea Pass *Aphis pomi* De Geer *Eriosoma lanigerum* Hausm	— biological control (conservation) — azadiracthin
	Panonychus ulmi (Koch)	— biological control (conservation) — mineral oil
	Quadraspidiotus perniciosus (Comstock)	— biological control (conservation)
	Ceratitis capitata Wiedmann	— biological control (conservation) — mass capture — spinosade or azadiracthin

Diseases	*Venturia inaequalis (Cooke) G.Winter* *Podosphaera leucotricha* (Ellis and Everh.) E.S.Salmon	— potassium permanganate — copper and sulphur — argile
	Nectria galigena Strasser	— cultural measures — copper

Source: Author table.

2.3. Should consumers be concerned?

Pesticides have been associated with health issues. The numerous negative health effects that have been associated with chemical pesticides include, among other effects, dermatological, gastrointestinal, neurological, carcinogenic, respiratory, reproductive, and endocrine effects. Furthermore, high occupational, accidental, or intentional exposure to pesticides can result in hospitalization and death (Covello and Merkhoher, 2013; Nicolopoulou-Stamati et al., 2016).

Human exposure to pesticides occurs through various routes (e.g., residues in food and drinking water) and the related hazards range from short-term (e.g., skin and eye irritation, headaches, dizziness, and nausea) to long-term (e.g. Parkinson's disease; asthma; depression and anxiety; attention deficit and hyperactivity disorder (ADHD); and cancer, including leukaemia and non-Hodgkin's lymphoma), being influenced by various factors (e.g., period and level of exposure, and type of pesticide (regarding toxicity and persistence). In fact, it is obvious that there are no groups in the human population that are completely unexposed to pesticides (Kim et al., 2017; PAN-Europe, 2020).

Residues of pesticides can be found in a great variety of everyday foods and beverages. In most cases, the concentrations do not exceed the legislatively determined safe levels (EFSA, 2019). However, these "safe limits" may underestimate the real health risk as in the case of simultaneous exposure to two or more chemical substances, which occurs in real-life conditions and may have synergistic effects, producing unknown adverse health effects (Nicolopoulou-Stamati et al., 2016).

More than ever before, today's consumer exhibits a desire to understand where food comes from and the magnitude and impact of dietary pesticide exposures (Green et al., 2016; Reeves et al., 2019). Stated-preference valuation studies have been carried out to assess consumers' willingness to pay (WTP) for the reduction in human health risks resulting from the application of pesticides (Florax et al., 2005; Skevas et al., 2013; Costa and Santos, 2016), to select the optimal level of health safety and set proper policies that incentive to farmers to switch to more environmental friendly forms of production avoiding pesticides.

Information on the riskiness of pesticides in relation to output realization may enhance the effectiveness of pesticide policy tools while evidence on the consumers' WTP for reducing pesticide-adverse effects can reveal if there is a demand for more environmental friendly products. So, policy makers may use this information by providing an incentive to farmers to switch to more environmental friendly forms of production (e.g., organic or Integrated Pest Management (IPM)).

3. What are the key evidence that support a need to reduce the use of pesticides and reinvent the food systems?

Detailed data on the indirect effects of pesticides can assist policy makers in setting proper environmental and health standards that can increase the effectiveness of the different economic instruments. WTP studies can be used to estimate the value of the benefits for human health resulting from the reduction or ban of pesticides through the implementation of different economic incentive-based policies (pesticide tax level, the subsidies or the price-differential in certification policies), providing incentives to farmers to switch to more environmental friendly forms of production. WTP estimates from other countries can be used in EU pesticide policy design (Florax et al., 2005; Skevas et al., 2013).

3.1. The impact of pesticides at the production level

Pesticides are included on variable costs: occur during a single production year and would not be incurred if production was stopped for some reason.

In the United States, the Agricultural Resource Management Survey suggest that, on average, the cost of production for organic apples is 9.5% higher than the costs for conventional production. The primary difference in costs appears to come from labour costs (Taylor and Granatstein, 2013).

Experiences in apple orchards, comparing the use or not of pesticides (using alternative crop protection measures, such as disrupting mating or biological control), shows that the tonnage of apples and growth indicators of apple trees were not adversely affected (Swezey et al., 1998).

Environmental indicators can be used to evaluate the impact on the environment (soil, water, biodiversity) and health (consumer and farmer), for relevant crops/regions, based on the use of different levels of pesticides (from intensive use to non-use).

Monitoring agricultural effects is necessary to ensure that its environmental effects will not threaten consumers, farmers, and environment. Environmental indicators can be used to evaluate the environmental consequences of agricultural activities over time and the relationships with the most sensitive environmental compartments (Galli et al., 2011; OECD, 2001; Primdahl et al., 2010).

To evaluate pesticide effects, we need to consider the impacts related to its use – on biodiversity (living forms and the complexity of relations between species and habitats), on human health, and on the environment (De Smet et al., 2005; Payraudeau and van der Werf, 2005). Environmental indicators are better understood if used and interpreted jointly, therefore the footprint methodology can also provide an assessment using several environmental indicators that complement each other, including economic and social indicators if necessary and possible (Galli et al., 2011). The footprint is, generally, based on the sum of all the relevant indicators related to the system that are scaled using several mathematical options (Borucke et al., 2013).

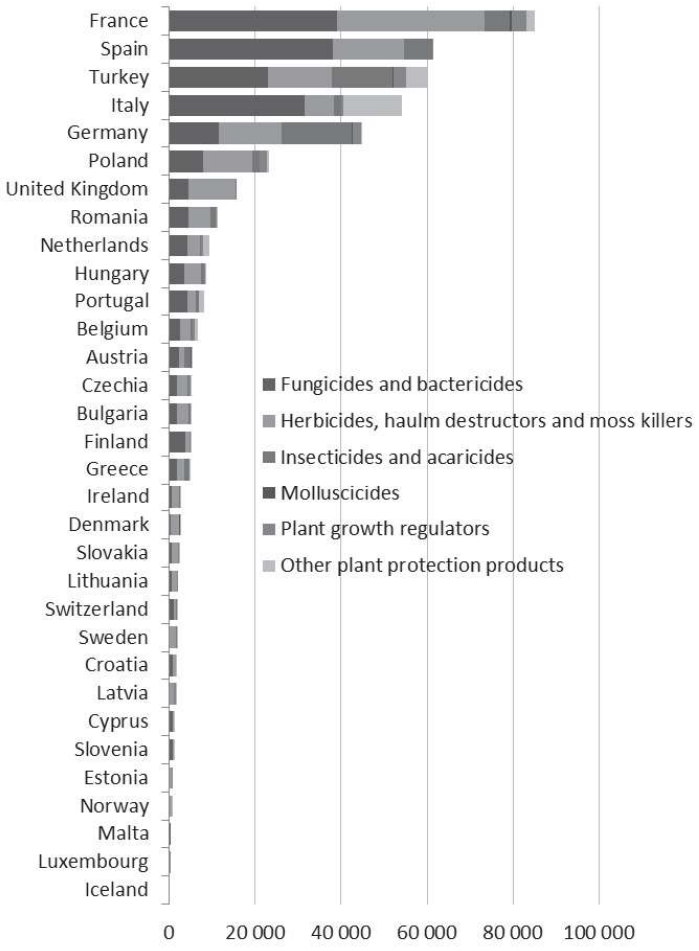
In Portugal, a study was conducted to assess the impact of pesticides in apple orchards, between 2005 and 2007, in different Portuguese regions (Dão and Oeste). Along with simple pesticide use indicators (Environmental impact quotient, EIQ - Kovach et al., 1992 - and Environmental Risk Indicator, e_tox and h_tox – OECD, 2001), a Pesticide print approach was calculated, based on the total amount of pesticides used and its effects on health and environment, including variables related with pesticide use impacts and its main environmental and health effects, sustainable agricultural practices adopted and farmers' knowledge and perceptions towards pesticide risks (Costa, 2016).

The expected pesticide impact, based on the total EIQ and farm worker, consumer, and ecological components and the e_tox and h_tox indicators were significantly higher in integrated pest management and conventional farms, where pesticides are used compared to organic farms (where pesticides where not used). Based on the Pesticide print, that includes variables related with pesticide use, biodiversity, and agricultural practices adopted, farms were pesticides were used presented a significant higher impact on environment and health (the Pesticide Print was 13.7 per ha). This impact is reduced in about 21.7% when farmers do not use pesticides (10.7 per ha).

Based on national statistics (pesticide sales and use), estimations of the potential reduction of pesticide use and its effects on food prices are presented.

In 2018, the total quantity of pesticide sales in the EU-28 amounted to almost 400 000 tonnes. Portugal among the countries in which the highest quantities of pesticides were sold (after France, Spain, Turkey, Italy, Germany, Poland, United Kingdom, Romania, Netherlands, and Hungary) (Eurostat, 2020), and together they made up 81% of the European pesticide sales (Figure 2). Considering the quantities of sold pesticides by utilised agricultural area (UAA), Portugal is also among the countries with higher amounts of pesticide per hectare, with more than 2kg/ha of UAA, which maintain Portugal among the European countries with higher levels of consumption per hectare of UAA (DGAV, 2018). This is due, specially, to the use of fungicides that amount for more than 50% of the pesticides used.

FIGURE 2: PESTICIDE SALES IN EUROPEAN COUNTRIES, BY MAJOR GROUPS, 2018



Source: Tonnes, Eurostat, 2020.

At present almost 46% of the food consumed in Europe contains residues of two or more pesticides, with 4.1% being above the maximum residue levels, according to the annual report published by the European Food Safety Authority (EFSA, 2019). For certain foods, the situation is much worse: more than 60% of the popular summer fruits tested (currants, sweet cherries, strawberries, and bananas) come with pesticide "cocktails". Furthermore, it is important to highlight the absence of a safety assessment for pesticide mixtures present in our food, which still fails to address the EU law requirements, and puts consumer health at risk in a clear violation of human rights (Pan-Europe, 2019).

There also exists a generalized ignorance about the 'un'sustainability of pesticide use that is forced by pesticide and seed/plant varieties companies whose productivity depends on intensive use of production factors such as pesticides (Wilson and Tisdell, 2001). Damage to agricultural land from the use of pesticides occurs over a period of time. Hence, costs arising may not initially look serious. Furthermore, farmers do not compensate for the numerous externalities except in the case of production externalities. It is also likely that in the majority of cases, the short-term health effects arising from pesticide use and the disutility from that ill health are underestimated by farmers. As Wilson and Tisdell (2001) demonstrates, when chemical agricultural systems are adopted, agricultural yields or returns become dependent on them despite the very high costs, and thus impose an 'economic barrier' to switching to organic systems. The use of chemicals can also affect biological pest control strategies by killing the predators of pests. Hence, even if some farmers decide to adopt biological pest control strategies, they would be affected due to externalities of pesticides arising from neighbouring farms.

From another point of view, agricultural policies in Europe, and in Portugal, should also be appropriate to smallholders and family farmers, the most prevalent form of agriculture in the world (more than 570 million farms in the world), and also in Portugal (93% of the registered farms are classified as family farms; these farmers are of most importance to local food availability, job creation, income and local economy diversification, but also for the preservation of the territories, biodiversity, social and cultural heritage, and constitute the most vulnerable group of farmers specially in terms of risks associated with farming, such as the use of pesticides, fertilizers, equipment, climate, etc. Unfortunately, regulations and laws, research, training, and technology, are not accessible or appropriate to the reality of these farmers.

The European plant protection industry, a significant economic player on the world market, with three of the five largest global companies based in Europe and employing almost 30 thousand people and involving several other companies such as manufacturers of spraying equipment, service companies for aerial spraying, and so on (European Commission, 2007), is a strong player that deeply influence, via advertising and promotion, farmers towards the adoption of pesticides, based on the idea of its effectiveness and cost.

Another issue that systematically challenges the implementation of pesticide regulations and restrictions to its use is the scientific discussion between science, environmental, agriculture and pesticide industry stakeholders. This discussion as led to the establishment of regulations on pesticide registration and distribution that are more demanding and costly to the industry and consequently to farmers.

So, even with the strong epidemiological and toxicological evidence for effects of pesticides on human health, using rigorous criteria and with high probability of a causal relationship, the pesticide industry and farmers organizations defend that these results are not enough to prove causality (Bellanger et al., 2015). Furthermore, these stakeholders, as well as policymakers in most developed countries, argued that pesticides are needed to “ensure” an abundant and affordable food supply for the world and that they are the only cost-effective choice for some crops (Trasande, 2017).

Scientists who raise their voices against pesticides often face criticism from those who have substantial vested interests, loose funding sources, grants, and partnerships, or are refused by many peer-reviewed publications with the adage that “further research is needed” (Bergman et al., 2015). At the same time, several cases of attacks by industry on the scientific credibility, ethics, and personal lives of researchers in this area are known (Aviv, 2014; Sauvé, 2019).

Some authors refer that pesticide-dosing studies are clad in ethical or scientific deficiencies such as “unacceptable informed consent procedures, unmanaged financial conflicts of interest, inadequate statistical power, inappropriate test methods and endpoints, and distorted results” (Lockwood, 2011). In fact, conflicts of interest may lead pesticide companies to generate data favorable to their products, employing different sort of strategies for biasing the research results (Resnik, 2007). Several studies sponsored by pharmaceutical companies tend to favor the companies’ products (Krimsky, 2004; Boone et al., 2014).

Under these circumstances, an important part of the knowledge is not disseminated, contributing to the maintenance of the status quo.

3.2. The impact of pesticides policies at the consumer level

Consumer's choice for environmentally friendlier and healthier products is a complex phenomenon that takes into account individual motives, from quality and healthfulness considerations to collective or social interests, such as a better environment. The factors that influence behavior towards healthier and environmentally friendly products referred to in Table 2 are grouped into two categories: psychological (motivations and perceptions towards health benefits, food safety and environment, knowledge of agricultural practices and certification systems, attitudes towards shopping attributes and agricultural practices and beliefs such as ‘green’ and pro-social ones) and personal (age, gender, family size, education, income and relation urban/rural). Results of these studies revealed to be inconsistent or to have opposite relations with the behavior towards healthier and environmentally friendly products.

TABLE 2: MOTIVATIONS REFERRED IN 60 VALUATION STUDIES FOCUSED ON CONSUMER'S BEHAVIORS AND INTENTIONS TOWARDS BUYING ENVIRONMENTALLY FRIENDLIER AND HEALTHIER PRODUCTS

		positive relation (%)	negative relation (%)	indifferent or little significance (%)
motivations	health benefits	62	2	3
	environment	57	3	
	food safety	28		
	product attributes and purchasing habits	37	2	3
	knowlegde of agricultural practices and certification systems	50	2	
	prosocial benefits	17	2	
personal	'green' attitudes	20	2	
	age	33	23	7
	gender[a]	43	8	7
	family size	20	17	3
	education	40	15	7
	income	40	10	5
	urban	12	3	

Source: Costa et al., 2016.

The main motives for consumer's preferences for environmentally friendly products referred to in the studies in Table 2 are health and environmental benefits, knowledge about agricultural practices and quality certification systems and some socioeconomic factors like gender, education, and income.

On the consumers side, it is known that a large part of the population is unaware of the use of pesticides and how different farming systems can contribute to reduce their use and produce safer and environmentally friendlier food (about 60% have little or no knowledge of the use of pesticides in agriculture and have little experience in buying certified food) (Costa et al., 2016). Therefore, the lack of consumers' knowledge and awareness concerning overall food production and processing systems, specifically pesticide issues, emerges as a key issue for policy and marketing strategies.

Costa and Santos (2016) proposed a method to analyse data collected in stated-preference surveys related to the demand for differentiated food products, namely those resulting from the agricultural systems that use less or no pesticides. The method estimates the probability of purchasing the differentiated product as a function of the price premium level, household income, level of consumption of the food item at stake, and knowledge about environmentally friendlier and healthier production systems.

The impact of the optimal price policy on the low-income groups (when compared to a zero-price premium policy) was also analysed. A price policy for the SUP sector that is consistent with the maximization of the gross revenue of the SUP sector will exclude about 80% of the consumers with low income, who will buy SUP at zero price premium, with a substantial increase of their vulnerability to pesticide use risks.

The effect of consumers' knowledge on demand for SUP food also revealed to be very significant. Improving consumers' knowledge and understanding of environmentally friendly farming systems and of the SUP will significantly increase the ability of consumers to make wiser judgments about healthier and safer food.

Consumer awareness of health and environmental safety has led to the design and application of policy tools for the dissemination of sustainable agricultural practices and of rules for the proper use of pesticides. Thereby, since 1979, the European Commission and each individual EU member countries have a long history of controlling pesticide use through a myriad of regulations (Table 3).

TABLE 3: PESTICIDE POLICIES IN DIFFERENT EUROPEAN COUNTRIES

Country	Pesticide policy description	Values for pesticide taxes/fess/levies (euros)
Sweden	Environmental tax per kg of active substances	€3.25 per kg of active substances
Norway	Banded tax system	Basic tax: €2.6 per ha; Per toxicity level - LT: €2.6 per ha; MT: 10.4 per ha; HT: 20.8 per ha [a]
Denmark	Differentiated pesticide tax Overall tax on all pesticides	Insecticides: 54% of retail price (rp) Herbicides/fungicides/growth regulators: 34% of rp Wood preservatives: 3% of gross value
Italy	Sales control, pesticide taxes	0.5% over the final price of domestic pesticides and 1% over imported pesticides
UK	Target fee for registration General fee for industry	Target fee: €5000 General fee: €5719
Switzerland	Direct payments, extra subsidies Minimum ecological standards	
Finland	Registration charge	€840 + 3.5% of final price
Netherlands	Integrated crop protection on certified farms	
France	Pesticide tax	Category 1: € per ton; 2: 381 per ton; 3: 610 per ton; 4: 838 per ton; 5: 1067 per ton; 6: 1372 per ton; 7: 1677 per ton [b]
Germany	Pesticide reduction program	
Belgium	Tax on five active substances	€0,395 per kg

a LT, MT and HT denote low, medium, and high toxicity pesticides, respectively; b Categories reflect different environmental load of pesticides, with 1 being the lowest and 7 the highest toxicity category, based on health and environmental criteria.

Source: Skevas et al., 2013.

The directives 91/414/EC and 98/8/EC on the placing of plant protection products and biocidal products on the market were the first ones dealing with the authorization of pesticides. The waste framework directive (2006/12/EC) and the directive on hazardous waste (91/689/EEC) constitute regulations impacting pesticide use in many ways, as they establish provisions for the safe collection/disposal of empty pesticide packages and unused or expired pesticides. The water framework directive (2000/609/EC) and the regulation on MRLs (396/2005) address pesticide residuals, where the first identifies substances that are hazardous for water (including active substances in plant protection products) and the second sets maximum residue levels of active substances in food and feed.

In Europe, the Directive 2009/128/EC established a framework for Community action to achieve the sustainable use of pesticides, where all farmers should adopt proper agricultural techniques or systems, such as integrated pest management or organic farming, to reduce the use of pesticides and its impacts on the environment and on human health. In Portugal, the Directive was implemented through a National Action Plan (DGAV, 2013, 2018) and a set of national laws, that set a frame of rules for the commercialization and use of pesticides (Law 26/2013, Decree-Law 35/2017 and Decree-Law 86/2010) (Appendice 1).

Since its implementation, the directive has not yielded the expected positive environmental and health impact. In fact, the use of pesticides on average in Europe did not decrease in recent years despite much debate on the sustainability of agriculture and the entering on the market of pesticides that can be used at low dose (PAN-Europe, 2019).

In Portugal, the agro-environmental measures that supported the adoption of integrated pest management (IPM) and organic farming (OF) between 1994 and 2013 have reduced the global impact of the risks associated with the use of pesticides (about 5% when compared with

conventional agriculture) (Costa, 2016). Nevertheless, several studies are referring that in fact farmers have not reduced the use of pesticides and that Portugal is on the top five countries using higher amounts of pesticides per hectares – in 2012 the average pesticide usage per hectare was 3.73 kg (Lamichhane et al., 2016; Costa et al., 2017).

This may lead to the conclusion that pesticide policies (such as the Directive for the sustainable use of pesticides and several other of international legal instruments and conventions), are not enough to ensure that pesticide use and risks are significantly decreasing with its implementation. In fact, the PAN International monitoring report indicate that highly hazardous pesticides are often used and that most farms do not use or have full personal protective equipment, by lack of ability, access or price (Weber, 2011).

The implemented policies are based on training in safe and effective pesticide use, codes of conduct on the distribution and use of pesticides, pesticide registration to make sure that only properly tested and approved pesticides are sold and the application of taxes according to pesticide risk.

A growing number of individuals and organisations no longer believe that training can achieve a so called "safe use" of pesticides, particularly among small-scale farmers who do not have access to enough training and proper equipment (FAO, 2010). Furthermore, it often proves impossible to restrict pesticide use to only those farmers trained in their use.

Some countries have supported programs to promote the adoption of more sustainable agricultural practices. A good example is the ECOPhyto program in France, based on the implementation of a network of thousands of farms that tested methods of reducing chemical use, improved national surveillance of pests and plant diseases, and funded research on technologies and techniques that reduce pesticide use. At the same time, that have imposed taxes on farm chemicals in a bid to decrease sales, and even banned numerous pesticides, infuriating many farmers (Stokstad, 2018), The program failed miserably: instead of declining, national pesticide use has increased by 12%. One major reason for this flop, was because farmers fear burdensome rules and increased costs that will put them at a competitive disadvantage.

Nevertheless, there are several agroecological approaches available to farmers that are alternatives to pesticide use, such as mixing crops, planting new varieties, biological and biotechnical control, etc. These alternatives require technical capacities that are not accessible to all farmers, demanding for appropriate training, but also that are associated with higher risks at farm level (Weber, 2011).

Thus, policy research is needed to understand what are the most suitable policies and measures that will contribute to an effective reduction of pesticide use and the environmental and health impacts that come with its use.

Besides the exclusion of toxic pesticides, a set of rules should be established, either by defining restrictions to the amount or to the number of treatments of each pesticide, by associating taxes to the most dangerous pesticides (pesticides that cause endocrine disrupting effects that are toxic to natural enemies and other living organisms, and for which there is evidence of causing other health problems), by supporting farmers who reduce pesticide use (creating incentives for the adoption of sustainable options that should deliver effective benefits, including limits to pesticide use), or by the development of information campaigns that increase consumers' awareness about health and environmental risks associated with pesticide use.

In fact, as policy tools have impact on food prices, incentives to farmers (e.g., agri-environment schemes), if appropriately designed, including selling price commitments, may deliver safer but not necessarily more expensive food, as costs will be supported by taxpayers. Regulation (e.g., pesticide withdrawal or taxes), as well as pesticide taxes will impose safer but more expensive food. Market differentiation will ensure that consumers have a choice between cheaper, but less safe food, and more expensive, but safer food, which would be justified only if income distribution was more equitable, and everybody could opt for the safer food (Costa and Santos, 2016).

To design balanced strategies to promote farming systems that use less or no pesticides, policy makers need to understand the effects of different policies based on certification, taxes, or regulation. It is also necessary to understand the mechanisms that keep the usage high (easy, riskless, and cheaper way to go from the farmers perspective, lack of technical alternatives, profits from the perspective of the pesticide industry, political arrangements between groups of stakeholders, scientific gaps, and misuse of the available knowledge) and to identify the triggers that might break the underlying logic.

The design of optimal pesticide policies requires insight into the relationships between production decisions on crop yields and their quality, the environmental and health spill over impacts of

pesticide use, how consumers address the issue of pesticide risks and how policies and regulations influence production decision making.

4. UNDERSTAND WHY THE CURRENT PESTICIDE POLICY NEEDS TO CHANGE

The health and environmental impact of pesticide use has been demonstrated to be 'un'sustainable both in the short and long term.

As a first issue to address, pesticides used have acute and chronic effects on farmers and consumers health and on the environment (groundwater, soil and air and air pollution and non-target organisms' secondary effects - birds, insects, fishes, among others). As there are no policy instruments that determine a compensation of these effects, the users (farmers) may keep using pesticides without having the need to choose the less harmless or alternatives to its use, choosing normally pesticides based on economic or efficiency reasons, without considering effects on humans (consumers and farmers) and the environment. Also, the damages caused (health, pollution) are paid by taxpayers, and a user-payer mechanism is not in place as it happens in other fields (tobacco, industry pollution, CO2 emissions, etc).

Pesticide policies grounded on certification processes that ensure consumers choice for food products without pesticides (the current situation, as there are no pesticide taxes neither subsidies to compensate the use of alternatives to pesticides or not to use them), result on higher food prices, due to the costs of certification, and the costs of adopting alternatives to pesticide use, or to lower productivities due to the no use of pesticides. In this situation, a significant part of the population does not have the economic capacity to buy food without pesticides, making them more exposed to health problems related with pesticide use, specially, people with low levels of income, usually more exposed to unbalanced diets. Such situation, together with the fact that a large part of the population doesn´t have enough knowledge about pesticide risks, will increase of the health problems related with pesticide residues in the food, water, and the environment, specially among people with less resources that are per si more susceptible due to inadequate diets, higher risks of health problems and less access to health care.

The previews to issues are related with human health and environment values, that are, nowadays, a major concern of the society and should be the first issues to be considered in pesticide policy design.

On the production side, producers with less levels of education or training, or with limited access to alternative solutions (for economic, social, or technical reasons) do not have the incentive to find alternative and more exigent pest control solutions because the use of pesticide is the easier and less expensive solution. These farmers keep using pesticides, impacting on their health, food products and the environment and even when facing these problems, do not have the energy and critical and technical capacity to adopt the alternatives.

Also, there are no specific rules setting limits to pesticide use per crop, year, area, or penalties for farmers that abuse on pesticide use without justification, or to the use of pesticides based on toxicity effects. Because of that, pesticide users (farmers) may use whatever amount of pesticides they want, without having the need to justify its use. The official controls to pesticide use are only based on field books auditing, that is mandatory, but only reflects the farmers' statement about the list of pesticides used per year, without a proper justification for each treatment – the risk assessment is not required - allowing an uncontrolled use of pesticides. Pesticides are also monitored by a national food sample, that reaches only a small part of the total number of farmers.

5. WHAT ARE THE PESTICIDE POLICY OPTIONS AT STAKE?

Pesticide policies grounded on economic incentives should include taxes (or subsidies) to control pesticide externalities, where the tax (or subsidy) reflects the marginal net damage (benefit) of pesticide use. The problem with such a policy framework is that obtaining an accurate estimate of the monetary value of pesticide damage (or benefit) is not an easy task mainly because of prohibitive information requirements (Skevas et al., 2013). Alternatively, a set of standards or targets for environmental quality followed by the design of a regulatory system that could employ taxes (or subsidies) to attain these standards may constitute the policy design.

A pesticide policy framework that combines market-based instruments with standards for acceptable environmental and health quality will enable policy makers to base the charge rates or prices on the acceptability standards rather than on the unknown value of marginal net damages (Pretty et al., 2001; Skevas et al., 2013).

The design and application of a pesticide policy framework grounded on market-based instruments and environmental and/or health standards, requires rigorous information on different dimensions and aspects of pesticide use. The elements needed by policy makers to apply such a policy framework may be summarized by information on (1) the production structure (i.e., production function, pesticide demand elasticities), (2) attitudes towards risk and uncertainty related to pesticides application, (3) the value of pesticides to consumers (e.g., the willingness to pay (WTP) for lower pesticide use), and (4) the indirect effects of pesticide use (Skevas et al., 2013).

5.1. Analysis of different policy options

Possible policies (Table 4).

1. Pesticide policy grounded on taxes over pesticides, based on their toxicity, to compensate pesticide externalities, reflecting the marginal net damage of pesticide use on health and the environment
2. Pesticide policies grounded on economic incentives (subsidies) to compensate the costs of using expensive pesticide alternatives, where the subsidy reflects the marginal net benefit of reducing pesticide use
3. Pesticide policies grounded on certification processes that ensure consumers choice for food products without pesticides (the actual policy)

TABLE 4: PESTICIDE POLICIES AND ITS GOALS AND CRITERIA FOR IMPACT ASSESSMENT

	Policy Options		
	1	***2***	***3***
Goals/criteria	Pesticide policy grounded on taxes over pesticides, based on their toxicity, to compensate pesticide externalities, reflecting the marginal net damage of pesticide use on health and the environment	Pesticide policies grounded on economic incentives (subsidies) to compensate the costs of using expensive pesticide alternatives, where the subsidy reflects the marginal net benefit of reducing pesticide use	Pesticide policies grounded on certification processes that ensure consumers choice for food products without pesticides (the actual policy)
Reduce de use of pesticides	10% to 20% (the pesticides with higher level of toxicity) (a)	More than 50% (based on data from countries where food price is not constraining preferences) (b)	Up to 50% (based on an increase of 7% of the organic area per year) (b)
Reduce pesticide use per hectare	Less than 2,24 kg/ha (c)	Less than 1,14 kg/ha (c)	between 1,36 and 1,14 kg/ha (c)
Increase food costs	10% to 20% due to pesticide costs	Similar	30% due to certification and pest protection alternative costs
Lack of alternatives to pesticide use	No risk	Higher	Higher
Shift consumption towards less harmful pesticides	High increase, due to pesticide costs	Medium increase, due to market demand and pesticide free food	Lower increase, due to market demand and pesticide free

		competition	food competition
Reduce diseases related with pesticide use	Lower	Higher	Medium
Consumption of safe food on the (vulnerable) segments of the population	Between 20% to 50% of consumers (the effect is higher in low-income groups) (d)	More than 70% of consumers (prices between conventional food and pesticide free food will remain equal) (d)	Between 20% to 50% of consumers (the effect is higher in low-income groups) (d)
Protect (increase) biodiversity	Lower increase of biodiversity	Higher increase of biodiversity	Medium increase of biodiversity
Decrease pesticide residues in food and water	10 to 20%	More than 50%	Up to 50%

a) Based on results of similar policies on Sweden, Denmark and Belgium; b) Pedersen et al., 2012; IFOAM, 2020; c) Average usage of pesticides per hectare in Portugal (2,78 kg/ha) towards 1,14 kg ha in Austria, where 50% of the agricultural area is organic (EEA, 2018); d) Costa and Santos, 2016.

Source: Author table.

5.2. Policy alternatives that should not be considered

"Pesticide policies grounded on certification processes that ensure consumers choice for food products without pesticides (the actual policy)"

Policies that promote market differentiation of pesticide free food products, where higher-cost food commands a price premium. Consumers will have a choice between cheaper, but less safe food, and more expensive, but safer, food. The preference for this food products depends on the consumer knowledge, willingness and economic capacity of choosing these food products, and the production will be restricted to a niche of the market.

This kind of policies, where consumers (and farmers) are free to choose between consuming food free of (or using) pesticides, are more appealing in democratic societies and consumers seemed to be attracted and ready to believe in the underlying warrantees. Unfortunately, these policies will lead to:

- Producer would choose the less risky and less expensive options (pesticide ones'), that are also easy to adopt;
- Consumers usually choose based on price;
- Vulnerable segments of the population usually do not have access to pesticide free food product (for economic and knowledge reasons).

A shift toward the consumption of pesticide free food products is only possible based on efficient and customized strategies of information and environmental and health education, as well as specific quality promotion and distribution strategies. Also, without appropriate price policies based on market differentiation will exclude low income and uninformed consumers (and farmers) with a substantial increase of their vulnerability to pesticide use risks. Furthermore, the costs of health care related to pesticide use impacts will be supported by taxpayers.

"Pesticide policies grounded on economic incentives (subsidies) to compensate the costs of using expensive pesticide alternatives, where the subsidy reflects the marginal net benefit of reducing pesticide use"

Policy tools based on economic incentives to pay the costs of using expensive alternatives to pesticide use or for the environmental services due to the non-use of pesticides - agri-environment schemes, adoption of alternatives to pesticide use or agroecology practices recognition, or other forms - may deliver safer but not necessarily more expensive food with costs being incurred by general taxpayers.

This kind of policies, where farmers are the responsible for choosing the most suitable crop protection scheme have proved to work properly when economic incentives are in place. Consuming between food free of pesticides will be an option for the consumers, as food products would have similar prices between conventional and pesticide free food products. The success of these policies depends on:

- Farmers technical capacity to find and adopt alternatives to pesticide use, usually with higher risk levels and higher level of technical complexity;
- Consumers will have the possibility to choose based on quality, at that would need an investment on education and information, so that consumers may recognize the benefits of food free from pesticides in opposition to size, aspect, colour, etc.

The effect of consumers' knowledge on demand for pesticide free food is very significant, and thus improving consumers' knowledge and understanding of environmentally friendly farming systems will significantly increase the ability of consumers to make wiser judgments about healthier and safer food.

5.3. Why the "Pesticide policy grounded on taxes over pesticides" is the best one

"Pesticide policy grounded on taxes over pesticides, based on their toxicity, to compensate pesticide externalities, reflecting the marginal net damage of pesticide use on health and the environment"

With pesticide policy grounded on taxes over pesticides - regulation (pesticide withdrawal) - consumers can obtain with or without pesticides at the same price. Pesticides taxes are imposed per kg of active ingredient, and can be established on the sales value, dosage, weight of active ingredient or the environmental impact of a product. The tax rate can be fixed or differentiated among product classes or toxic content; it can be set as a fixed amount or as a percentage. From a revenue generation standpoint, a single, uniform ad valorem tax is the simplest solution and with low administration costs. From an economic perspective, a differentiated tax that takes account of the environmental damage caused by different types of pesticides is the preferred solution, since it provides more targeted price signals to the market and more adequately reflects marginal damages. Obtaining an accurate estimate of the negative externalities produced using pesticides/fertilizers is not simple and requires evidence-based research. In fact, there is a trade-off between maximizing revenues with a simple and uniform tax against more complex but differentiated rates based on the toxic content, which are more effective from an environmental standpoint.

This kind of policies, where farmers are the responsible for choosing the pesticides based on their personal beliefs, judgment, and economic interests, have pros and cons:

- It is a relatively easy tax to collect and administer when a simple design is chosen.
  directly address market failures by incorporating the social and environmental cost of using pesticides/fertilizers.
- Provide an incentive to shift farmers and commercial agriculture enterprises towards more sustainable cultivation practices.
- May increase food product costs, if farmers continue to use pesticides; but food products based on agroecological practices, such as organic food, will be at the same prices.

This policy option would be the easiest to implement, putting all responsibility and decision over the farmer. If the taxes will be high enough, naturally we could expect that farmers will look for cheaper solutions, choosing pesticides only when no other solution exists (philosophy under the concept of integrated pest management). If it also imposes a limit to the total number or amount of pesticides per hectare, it will become mandatory to farmers to adopt global decision-making processes based on low levels of pesticides. Restricting the quantities of pesticide used in fruits and vegetables might cause yields to decrease to a significant extent in the absence of low toxicity alternatives.

Nevertheless, farmers would be able to still use pesticides, and that would probably increase the price of food products due to the high cost of pesticides or the cost of the penalties paid due to the overuse of them. The low-price elasticity of demand suggests that without high rates there will be only minor effects in pesticide use reduction.

The main reason against this kind of policy, is that consumers with low levels of income will be severely jeopardized, as the global food basket cost would increase. Also, the tax on pesticides may be too high for poor and small farmers, specially family farmers (more than 85% of the Portuguese farmers).

At the same time, other risk to consider will be the possibility that several mechanisms and big company policies can be put in place to neutralize these effects, the existence of conflicting interests can create tensions among agricultural producers, agribusinesses, pesticides producers and consumers, tax evasion that can reduce the amount of resources mobilized.

Probably, an option that merges Policy option 1 and 2, based on the transfer of the taxes over pesticides to subsidize farmers that adopt alternatives to pesticide use, will be the best. In fact, it would allow generating a double dividend if the resources mobilized are used to reduce distorting forms of taxation or if they are reinvested in organic agriculture or other sustainable agriculture practices.

6. Conclusion and recommendations

The proposed research will contribute to the discussion of policy measures that aim to achieve a reduction in the use of pesticides, giving evidence to support the choice of the most adequate one.

The timing of the study is relevant, as Europe is preparing a long-term planning for the 2021-27 Common Agricultural Policy and Portugal should set up its national rules and programs to fulfil its objectives. Furthermore, society is increasingly concerned with food safety, health, and environmental issues demanding solutions that ensure their welfare and the future of the next generations.

Our recommendation is that a pesticide policy grounded on taxes over pesticides, based on their toxicity, to compensate pesticide externalities, reflecting the marginal net damage of pesticide use on health and the environment should be implemented.

A key message, strong and assertive should be considered since the beginning of the advocacy plan implementation:

- We need to have **healthy and safe food**. We need to **safe our agricultural landscape and patrimony**;
- So, we have to **discuss and create the opportunities to change our approach to the food system, renewing it without pesticides**;
- If nothing else, **decades of organic farming and age-old agroecological knowledge** show this transformation is possible.

The main actors to involve are:

- Consumers and health professionals that have, nowadays, a major influence in the consuming processes, specially due to the current knowledge about the influence of the human diet on its health, specially in diseases, such as cancer, obesity, dementia, among others. The increasing demand for organic and safe food legitimates the role and importance of these stakeholders.

- Environmental non governmental organizations (NGOs) are familiar with the discussion, have their one channel that can be used to promote the debate and are willing to have research evidence-based to support their activities. They will have a full comprehension of the problem and are used to set similar actions
- Farmers are the real promotors of the proposed changes. Successful examples are the stronger voices to convince other farmers that might not trust the alternatives. They are also the ones that take the risks.
- Journalists and media players can raise our voices to achieve wider publics and reach policy makers, moving hem towards the necessary changes

In parallel, it is relevant to get media support (national television and radio, newspapers), promoting debates involving journalists, scientists, consumers, farmers, and deputies from different political spectrums, and also to involve the international stakeholders, that have experience and a voice in similar campaigns.

Food, industry and industrial farmers lobbies are the strongest one's in the sector and will oppose to any recommendation that influence agricultural productivity and returns. Their involvement is mandatory, despite the result.

Deputies are crucial to ensure the debate occurs in the parliament and to defend our recommendations. Some groups defend political agendas that in some cases have goals that are common with the proposed changes, namely the green party, the left party, and other that are more concerned with environmental issues. Discussions in the sectorial commissions and in the plenary will contribute deeply and are necessary to promote the approval of any recommendations. An effort should be considered, to find the necessary support so that policy recommendations are presented and discussed in the parliament, via governmental departments, parliamentary deputies or civil society movements (petition to parliament).

Policies and programs to support any activity in the agricultural sector are designed by governmental departments[165]. Discuss, agree and consensus on the right proposal/ recommendations should be a target looking forward to obtaining an agreement to introduce the debate on the governmental agenda.

APPENDICE 1: POLICY TOOLS FOR THE DISSEMINATION OF SUSTAINABLE AGRICULTURAL PRACTICES AND OF RULES FOR THE PROPER USE OF PESTICIDES

Year	Policy/Regulation	Aim
	Europe	
1979	Council Directive 79/409/EEC	conservation of wild birds
1991 and 1998	Directives 91/414/EC and 98/8/EC	authorization and placing of plant protection products and biocidal products on the market
1991 and 2006	Directive on hazardous waste (91/689/EEC) and Waste framework directive (2006/12/EC)	regulating the impacts of pesticide use in many ways and establish provisions for the safe collection/disposal of empty pesticide packages and unused or expired pesticides
2000	Water framework directive (2000/609/EC)	addressing pesticide residuals and identifying substances that are hazardous for water (including active substances in plant protection products)
1991	Directive 91/414/EC	Thematic Strategy on the Sustainable Use of Pesticides
2005	Regulation on MRLs (396/2005)	maximum residue levels of active substances in food and feed
2009	Regulation No. 1107/2009	placing of plant protection products on the market
2009	Directive No. 2009/128/EC	sustainable use of pesticides

[165] Office of Planning, Policy and General Administration (GPP - Gabinete de Planeamento, Políticas e Administração Geral), Directorate General of Food and Veterinary (DGAV - Direção Geral de Alimentação e Veterinária), Portuguese Environment Agency (APA - Agência Portuguesa do Ambiente), among others.

Portugal		
2010	Decree-Law 86/2010	inspection of professionally approved pesticide application equipment
2013	Law 26/2013	sustainable use of pesticides
2013 and 2018	National Action Plan	National Action Plan for the sustainable use of pesticides
2015	Law 145/2015	placing of pesticides on the market
2017	Decree-Law 35/2017	distribution, sale and application of pesticides for professional use

Source: Author table.

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